1. **Project Name:** High Energy Density Coating of High Temperature Advanced Materials for Energy Efficient Performance

2. **Lead Organization:** Department of Materials Science & Engineering
University of Tennessee
10521 Research Dr., Suit 400, Knoxville, TN 37932

Materials Processing Group, Metals and Ceramics Division
Oak Ridge National Laboratory
P.O. Box 2008, Oak Ridge, TN 37831

3. **Principal Investigator**:

? Narendra B. Dahotre, (865)974-0523 (T)/(865)974-0530 (F)
Email: ndahotre@utk.edu

? Vinod K. Sikka, (865)574-5112 (T)/(865)574-4357 (F)
Email: sikkavk@ornl.gov

4. **Project Partners:**

? Cummins Engine Company, Inc., **In-Kind**, supply and evaluate test coupons and prototype components for processing by proposed method
Contact: Paul C. Becker, Director, Metallurgical Services; Ph: (812) 377-5000

? STOODY, **In-kind**, provide background and experience related to weld overlay problems in steel, power industries, provide weld overlay coupons for coating, evaluate the overlaid samples
Contact: Ravi Menon, VP Technology, Ph: (502) 781-9777, Fax: (502) 843-4228

? Hydro Resources Solutions, LLC , **In-kind**, provide guidance and consultations on currently used materials for hydroelectric energy generation, provide prototype turbine parts, conduct cavitation erosion tests
Contact: Patrick A. March, General Manager, Ph: (865) 599-6437
Email: pamarch@tva.com

? Applied Thermal Coating ,**In-Kind**, identify areas for corrosion and wear in power, chemical and paper industries, provide test coupons, test coupons
Contact: Harley Grant, President, Ph: (423) 267-0647, Fax: (423)267-0637

? Weyerhaeuser, **In-kind**, provide guidance and consultation on currently used refractory materials, provide refractory materials for coating, conduct corrosion tests,
Contact: J Peter Gorog, Senior Engineering Advisor, Energy & Recovery R&D
Ph: (253) 924-6514, Email: peter.gorog@weyerhauser.com

5. **Date Project Initiated and FY of Effort**: 8/1/2001 and Fiscal year 2

6. **Expected Completion Date:** 12/31/2003

7. **Project Technical Milestones and Schedule:** (Please provide the milestones/deliverables schedule for your project, both completed and planned.)

Description	Completed Date	Planned Completion Date
? Laser Coating Experiments	June 2002	-----
? IR Coating Experiments	July 2002	-----
? Microstructural Analysis	October 2002	-----
? Mechanical Testing		
Hardness Testing	December 2002	-----
Wear Testing	December 2002	-----
? Corrosion/Oxidation Testing	--------	August 2003
? Integrated IR/Laser Trials for Coating	--------	August 2003
? Modeling Based on Microstructural Analysis	-------	October 2003
? Coating of Industrial Components	-------	July 2003
? Industrial Trials of Coated Components	-------	July 2003

8. **Past Project Milestones and Accomplishments:**

- ? Intermetallic FeAl coatings have been successfully processed on 4340 steel using **laser** and **IR-based** techniques.
- ? Composite coatings (hard ceramic particles in steel matrix) have been successfully processed using **IR** and with limited success by **lasers**.
- ? Microstructural characterization using optical and scanning electron microscopies has been performed.
- ? Identification and characterization of phases within coating using x-ray diffraction and EDS has been performed.
- ? FeAl and composite coatings are characterized for mechanical properties using microhardness and dry sliding block-on-disk wear tests.
- ? Both coatings provided high hardness (> 2 fold) and wear resistance compared to the substrate material (4340 steel)

9. **Planned Future Milestones:**

- ? More trial runs for composite coatings without any cracks will be conducted at lower laser energy input.
- ? Elevated temperature oxidation studies will be performed on both types of coatings (schedule is provided in item 8)
- ? Thermodynamic model of phase evolution during coating will be attempted (schedule is provided in item 8)
- ? Integrated IR/laser trials for coatings will be performed for possible unique physical and microstructural characteristics (schedule is provided in item 8)
- ? Coatings of limited number and types of industrial components will be performed and they will be tested in industrial applications (schedule is provided in item 8)
- ? If time and resources permit, transmission microscopy work will be performed on the coatings to further understand the phase evolution behavior. This work will continue until the end of the project.

10. **Issues/Barriers:** (Provide a brief description of any technical problems or barriers encountered and how these problems have been or will be resolved or significant deviations from original scope and/or budget.)

    - There are no significant barriers encountered so far in synthesizing the coatings on steel using IR and laser based techniques. However, it was recognized that the total duration (two years) of the project is not sufficient enough to explore the technique and testing of similar coatings on nonferrous (Al-alloys) substrates/components which is a part of the original scope of the proposal. Attempts may be made during remaining short duration (about 4 months) of the project to explore the technique for non ferrous alloys.

    - On the contrary, PIs are successful in synthesizing FeAl coatings on steel using both laser and IR based techniques. Synthesis of aluminide coatings was not the part of the original scope. Such deviation was adapted to suit specific types of industrial applications involving high temperature oxidation and corrosion resistance. This deviation in approach is more justifiable due to lack of any technique to produce sound aluminide coatings in the thickness range of 50-500 microns.

11. **Intended Market and Commercialization Plans/Progress:** (Describe the end-use application and market potential for the research, and the plans and progress for commercial application/adoption, where appropriate; be sure to identify what the product of the research will be and how this product will be introduced/disseminated to the appropriate IOFs.)

    - The major product of this research efforts will be coatings for wear and oxidation resistance
    - The secondary product of this research efforts will be a technique (laser and IR based) to produce these coatings
    - Due to participation of 5 industrial organizations from various sectors it is expected that these participants will identify applications for these coatings and coating techniques.

12. **Patents, publications, presentations:** (Please list number and reference, if applicable.)

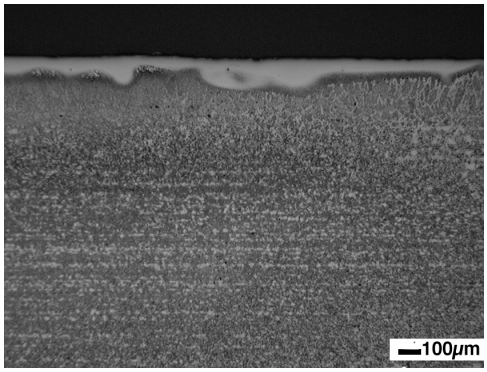
    1. **Laser Assisted Surface Modification of 4340 Steel with Iron-Aluminum Alloys**, G.Muralidharan, P.G. Engleman. C.A. Blue, V.K. Sikka, A.K.Singh, A. Khangar, and N.B. Dahotre, in **Surface Engineering 2002--Synthesis, Characterization and Applications**, MRS Proceedings Volume 750, Editors: A. Kumar, W.J. Meng, Y-T. Cheng, J. Zabinski, G.L. Doll, S. Veprek.

Highlight

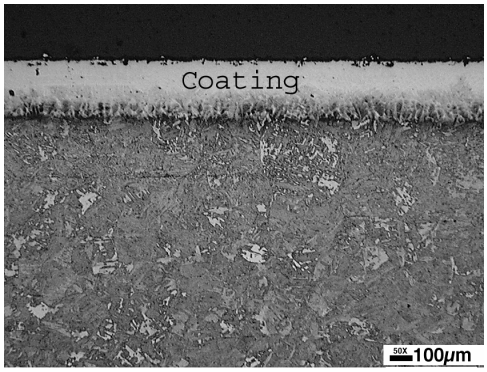
Objective: The objective of the project is to process coatings with superior wear and oxidation resistance on low cost steels using high energy density heating techniques such as a UV laser and an Infrared Lamp. Such coatings will enable achievement of improved energy efficiency.

Results Achieved:

1. Continuous, defect-free coatings based on FeAl, a material with good oxidation resistance, have been processed using UV- laser, and the IR Lamp.

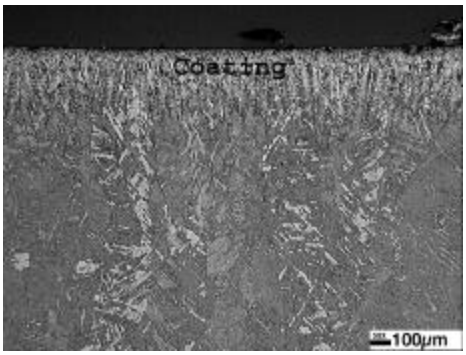


Laser

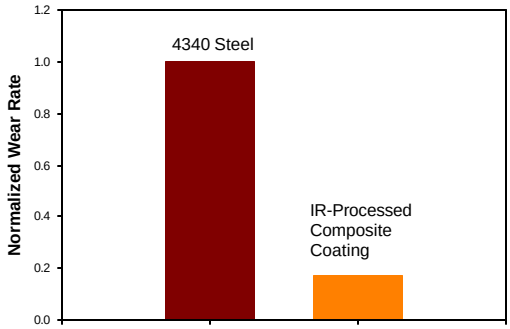


IR

2. Composite coatings with improved wear resistance have been processed using the IR lamp.



IR



Significance to IOF:

Both coatings of FeAl and carbides are of great importance and interest to many of the IOFs. The FeAl coatings are useful for oxidation and sulfidation resistance and carbides for wear resistance. These coatings would benefit chemical, mining, and pulp and paper IOF. Energy and cost savings will result from improved corrosion/oxidation and wear resistance through these coatings.